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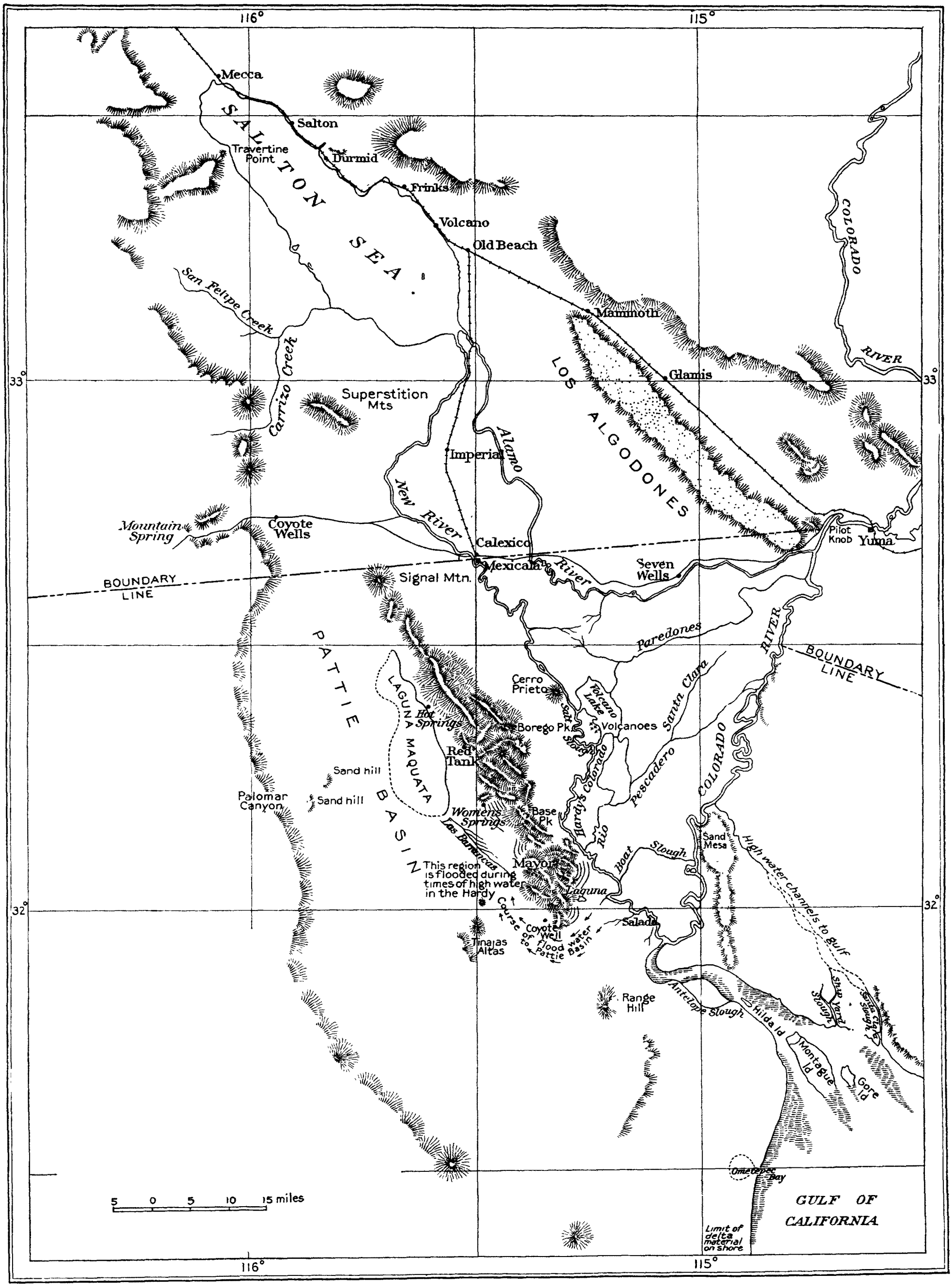


FIG. I.—MAP OF THE DELTA OF THE COLORADO RIVER, INCLUDING THE SALTON AND PATTIE BASINS. COMPILED AND DRAWN BY GODFREY SYKES.

Bulletin, American Geographical Society, December, 1907.

BULLETIN

OF THE

AMERICAN GEOGRAPHICAL SOCIETY.

Vol. XXXIX **1907.** **No. 12**

THE DESERT BASINS OF THE COLORADO DELTA.

BY

D. T. MACDOUGAL.

With Map by MR. GODFREY SYKES.

Attention has been focussed almost continuously upon the Salton Sea since the water of the Colorado River began pouring into it in the winter of 1904-1905, and numerous articles upon this newly re-formed body of water have been written from the scene of the struggle of the engineers at the break in the river bank and from the point of view of the windows of passing cars. Announcements and counter-announcements have followed each other as to the genius, and as to the failures of the engineers in closing the break, and as to impossible rises and subsidences of the level of the lake. Many of the articles have appeared with footnotes inserted with the final proof, which recorded more recent whims of the flood, and which in effect nullified the fine-drawn conclusions as to engineering methods and wise prophecies of the authors as expressed in the body of the paper.

A moderate acquaintance with the resistless lash and play of the tongue of the current of this great river about its delta leads to extreme conservatism in predicting what it may not do. Some general features of the topography and drainage of the delta were described in this BULLETIN for January, 1906, and the discovery of a new flood-channel between the lower river and the Gulf of California was recorded on the accompanying map. A continuation of the investigation of the region has been carried out by expeditions from the Desert Laboratory of the Carnegie Institution, and a somewhat more comprehensive conception of the extent and nature of the delta in question is presented in the following pages.

The most recent expedition was made in February of the present year, when the Salton Lake was circumnavigated from Mecca, California, as a starting-point, and an overland trip was made through the Pattie Basin, around the Cucopa Mountains, and through the delta lands near the main river-channel.

The delta, as ordinarily accepted, comprises the alluvial areas adjacent to the present channel of the river extending from a short distance above Yuma and spreading fanwise to the southward, where the river meets the Gulf. The deposition of this alluvial soil is believed to have resulted in cutting off the arm of the Gulf running northwestward far into California, which is ordinarily known as the Salton Basin, but which was designated as the Cahuilla Valley by Prof. W. P. Blake, a half century ago, in description of the general geological features of the region as found by him when engaged with the Williamson Expedition.

The depressed area to be included within the Cahuilla Valley may have been a marine body of water until the deposition of silt and the action of the tides closed the last channel and cut off direct communication between the Gulf and the depressed basin. Having been once cut off, the subsidence of the water in this Lake Cahuilla must have followed, as governed by evaporation and the inflow of river water. The bed was left as a great depressed basin, the bottom of which lay far below the barrier of mud that interposed between it and the waters of the Gulf. Into this basin at irregular intervals the main current of the Colorado has flowed at various times, filling it to a depth, perhaps, of 22 feet above mean tide-level as indicated by the ancient beach-line, and depositing here its burden of silt, and in effect making it a part of the alluvial-covered delta lands. The reversion of the river floods to channels running to the Gulf allowed the lake to recede by evaporation, leaving the salts carried in by the river water. Scores of times this must have been repeated. With each succeeding influx of water from the river, the deposited salts were dissolved, to be laid down again with the drying of the lake along with the increment brought in by the most recent inflow. Prof. R. H. Forbes, director of the Agricultural Experiment Station of Arizona, who has kindly undertaken the analysis of the waters collected by our expeditions, has called attention to the fact that the salts in the waters of the lake are in a combination which approximates more nearly a concentration of water from the Colorado River than it does sea-water. The repeated flooding of the basin has covered any sea-salt that may have been present with silt, and the deposits taken up by the floods entering the basin are those left there by previous evaporations.

The exact source of all of the components is, however, not yet made out. The following table gives a detailed determination of a large sample of Salton water taken from over the region of greatest depth June 3, 1907, by Dr. W. H. Ross of the Agricultural Experiment Station of the University of Arizona:

ANALYSES OF WATER OF SALTON SEA AND OF COLORADO RIVER AT VARIOUS STAGES.

	Salton water, surface of deepest portion, June 3, 1907.	Colorado river water, low winter stage, Jan. 10-Mch. 26, 1900.	Colorado river water, rising summer stage from melting snow, Mch. 27-Apr. 30, 1900.	Colorado river water, summer flood from melting snow, May 1-June 29, 1900.	Colorado river water, low summer stage, June 30-Aug. 26, 1900.	Colorado river water, affected by local floods, Aug. 27-Oct. 1, 1900.	Colorado river water, summer floods from Arizona, Oct. 2-Nov. 19, 1900.	Colorado river water, low winter stage, Nov. 20-Jan. 24, 1901.
Total soluble solids at 110C. Parts in 100,000....	364.8	92.9	67.4	32.2	36.1	71.4	104.5	87.1
	Complete analysis of soluble salts, stated by ions. Parts in 100,000.							
Sodium, Na.......	111.1	19.0	15.3	5.5	7.6	14.6	18.2	16.0
Potassium, K.....	2.3	1.1	2.1	1.0	1.3	1.8	2.1	1.2
Calcium, Ca.......	9.9	7.5	4.9	4.2	4.6	7.7	12.5	9.2
Magnesium, Mg...	6.4	3.1	2.0	1.2	1.2	2.2	2.8	2.8
Aluminum, Al....	.031	—	—	—	—	—	—	—
Iron, Fe..........	.005	—	—	—	—	—	—	—
Chlorine, Cl......	169.7	20.5	13.9	4.5	6.9	15.8	17.5	18.1
Sulphuric, SO_4 ...	47.6	26.1	19.4	7.2	7.6	19.7	35.6	23.8
Carbonic, CO_3....	6.6	7.4	8.4	7.2	7.7	10.0	12.2	10.7
Silicic SiO_3.......	1.2	4.6	2.1	2.1	3.3	2.3	2.2	2.1
Phosphoric, PO_4..	.018	—	—	—	—	—	—	—

In communicating the above data, Professor Forbes comments as follows: "The determinations show a difference in character between the Colorado waters and the Salton water, which our previous partial analysis did not reveal. If you will compare Salton water with the Jan. 10-March 26 sample you will notice that the proportion of chlorine to soluble solids is 1:4½ in the Colorado water, while in the Salton water the proportion of chlorine to soluble solids is 1:2, which means that the proportion of salt is more than twice as great in Salton water.

"Also, comparing the same sample with reference to SO_4 you will see that in the sample of river water of Jan. 10-March 26 the proportion is 1:3½ of soluble solids, while in Salton water the proportion of SO_4 to soluble solids is 1:8, which is to say that the river water is proportionally stronger in sulphates than the Salton water.

"This makes it appear as if the soluble matters of Salton sea are not exclusively derived from the Colorado River. Either the surrounding mountains have contributed their modifying materials to the sink in times past, or certain separation changes have taken place in the salts which may have been at various times, more or less remote, laid down by the river, or these salts are in part derived from the sea. . . . The data on Salton water are not quite complete, but the essentials are all there. Dr. Ross is yet to make certain determinations of small quantities of nitrogen, organic matter, and perhaps lithium, which will not affect the general results given."

It is instructive to recall the fact that every thousand parts of sea-water contain about 34.40 parts by weight of mineral matter in solution, the principal components being represented by the following table:

Sodium chloride	77.758
Magnesium chloride	10.878
Magnesium sulphate	4.737
Calcium sulphate	3.600
Potassium sulphate	2.465
Magnesium bromide	.217
Calcium carbonate	.345
Total	100.000

(Geology, Chamberlain and Salisbury, 1:309, 1904.)

As a result of inequalities of leaching action when the basin is empty, and of the rise of salts from below, the floor of the ancient lake shows loam, bearing alkali in varying proportions in different areas when dry; which, of course, constitutes an important factor in any agricultural consideration of the region. In the western portion clay forms the floor of the desert upon which in some places a thin layer of gravelly soil rests, while in other places the bare clay does not afford a foothold for plants of any kind.

The alluvial fan of Carrizo Creek comes down into the valley from the southwest, bringing great quantities of sand, which is piled up in dunes of the uncommon crescentic form. Similar formations occurring in the desert of Islay in Peru have recently been described by Professor Solon Bailey (The Sand Dunes of the Desert of Islay. Ann. Astronom. Observ., Harvard College, 39; Pt. 2, 287, 1906), and lunar dunes in Seistan, Persia, are described by Sir Henry MacMahon (*Geographical Journal,* 28; No. 4, 333, 1906). Dunes of this form are supposed to be due to the action of a wind blowing steadily in one direction, which in this instance is from the southwest. The Carrizo dunes are moving toward the bottom of the depression, which by the latest surveys is 286 feet below the sea-level. Lunar dunes also occur on the coast of California.

The tips of the crescent thin down to a few inches in thickness, and the central part of the half moon of sand is often as much as 15 or 20 feet in height, with a long gentle slope to windward, but dropping off as steeply as sand may be piled to leeward. The progress of these dunes results in disaster to plants covered by the heavier portions of the dunes, which move so slowly that death ensues before the shoots are uncovered. Individuals which have been encroached upon by the thinner cusps, however, bend down under the slighter weight, and send up branches from lateral buds surviving until the dune has moved on.

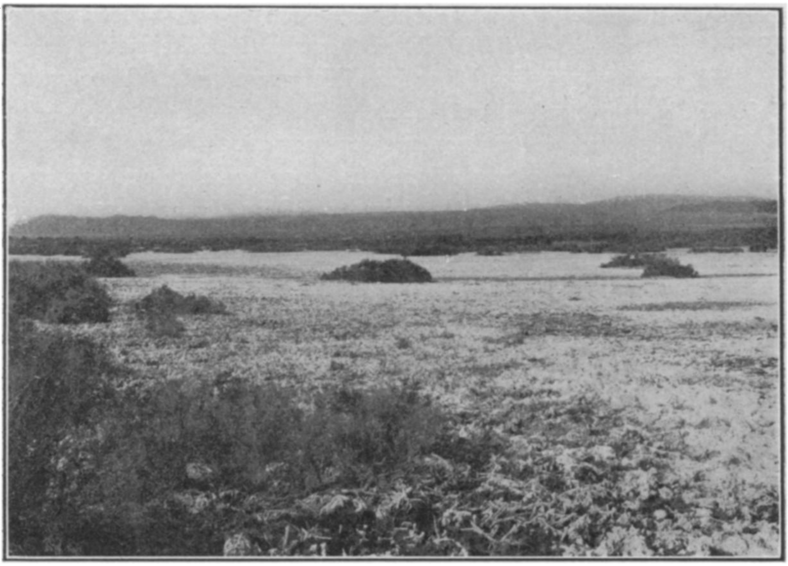


FIG. 2.—FLOOR OF SALTON BASIN, 286 FEET BELOW SEA-LEVEL, WITH INCRUSTATION OF SALT. FEBRUARY, 1903.

The Carrizo slopes bear numerous seepages or slow springs of salty water; and as sand is moved along by the wind either loosely or in dunes, some of it is wetted and remains in place. The moist heap thus formed serves to anchor additional particles until a mound some feet high is formed which affords lodgment for a few shrubs, including a scraggly mesquite. The roots of these plants bind the sand together and the small colony of plants in this formation may survive for some time as a prominent feature of the landscape, visible for some distance. The seepage may decline or the sun may dry out and allow a portion of the sand to be moved by the wind, with the result that the whole dune may disintegrate with the death of all of the plants. Such dune formations, while intact, serve as a retreat for numerous desert rats and small rodents, and their burrows penetrate the mass of roots and sand in all directions.

The Cahuilla Valley, as part of the Colorado Desert, bears a characteristic xerophilous vegetation. Along the clay strata in an upper level, bands and groves of the California palm (*Neowashingtonia filifera*) form characteristic oases of striking aspect. At other places around the springs, which are generally alkaline, mesquite (*Prosopis*), salt grass (*Distichlis spicata*), the rare rush (*Juncus cooperi*), which here is to be found in great tufts, *Cyperus,* and *Scirpus olneyi* occur in abundance.

The salt bushes (*Atriplex canescens* and *A. Polycarpa*) grow on saline areas; but in places where the loam bears more than 3 per cent. of alkali but little is to be found besides *Allenrolfia* and *Sueda,* and these are generally in the shallow drainage-ways, from the soil of which some of the salts have been leached.

Parosela spinosa, one of the most striking of all desert shrubs, is to be found on the margins and in the beds of the dry streamways well up on the sides of the basin, and also *Gaertneria,* with its burr-like fruits. *Ephedra, Parkinsonia torreyana,* and *P. microphylla, Fouquieria splendens, Olneya tesota,* and *Yucca mohavensis* are also here in abundance, while the creosote bush shows its characteristic wide range of adaptability to a great variety of soils.

It is to be seen that most of these plants are of the halophytic, or of spinose types, while but few plants capable of water storage are present. Among these is an *Echinocactus, Opuntia Bigelovii, O. basilaris,* and *O. echinocarpa.*

The rainfall of the region does not exceed three inches annually, and very high temperatures are reported for various points within the basin.

An area of a few square miles at the bottom of the basin bore a heavy deposit of salt, which was collected and prepared for the market by the New Liverpool Salt Company, while the loam, sandy, and gravelly formations making up the sides of the basin were variously impregnated with salt and alkali. The water from the Colorado began pouring into the basin early in 1905, and when its level was 273.5 feet below sea-level, or 12.5 feet above the bottom of the bowl, a gauge was established near the station of Salton, and the succeeding rise as given by the Los Angeles *Times* for May 19, 1907, was as follows:

MONTHS.	*1904.*	*1905.*	*1906.*	*1907.*	TOTAL.
January	..	1.4	1.1	2.8	..
February	..	1.6	1.8	1.7	..
March	..	0.8	2.7	0.1	..
April	..	1.2	5.6	..	..
May	..	1.0	8.7	..	..
June	..	2.2	15.5	..	..
July	..	4.4	8.5	..	..
August	..	2.2	2.2	..	..
September	..	1.2	1.0	..	..
October	..	1.4	1.2	..	..
November	0.6	1.6	0.2	..	..
December	0.2	2.9	1.2	..	..
Total	0.8	21.9	50.0*	2.4*	72.1*

"A maximum depth [above gauge] of 72.2 feet was reached in February, 1907.

The receding of the water during November, 1906, was due to the temporary closing of the break in the Colorado River, and the evaporation from the lake surface."

The water thus poured into the basin began, of course, to take up the salts from the soil with great rapidity. Furthermore, the water spread out over the gentle gradients so rapidly, and with so little opportunity for general circulation, that a marked difference was found between the amount of salts carried in the shallower and deeper places. Thus on June 10th, 1906, when the greatest depth of the lake was between 40 and 50 feet, water 1½ miles from shore near Mecca contained 401.6 parts of solid in 100,000, while at the same time a sample taken 100 feet from the shore showed 697.4 parts of solids. 1152.8 parts solids were found in a sample taken within a few feet from the shore near Travertine Point on May 23, when the margin was being pushed out over a saline flat. The currents set up by the summer winds and their facilitation by the increased depth led to greater uniformity within a short time, and on October 11, 363.2 parts in 100,000 were found in shallow water near the shore, while a half mile out a sample yielded 359.6 parts. This equalizing action continued so that in the first ten days of February, 1907, when the lake stood at its maximum, samples taken at various places yielded from 321.8 to 352. parts, showing a practical uniformity. The only marked departure from this general composition was to be found within a few miles of the mouths of the inpouring Alamo and New rivers, which at the time the samples were taken were bringing in only seepage water, the inflow from the break in the Colorado having been stopped (see 9 of table). The data bearing out these statements are given in the following table, kindly furnished by Prof. R. S. Forbes, Director of the Agricultural Experiment Station of Arizona, who has carried out extensive analyses of samples secured on the various Expeditions from the Desert Laboratory:

---

* These footings should read: 49.7 4.6 77.0.

FEBRUARY, 1907.	Total Solids at 110° C.	Chlorine, stated as Na CO.	Hardness by Heburs test, stated as Ca SO4.	Sulphates by Ba SO4, stated as SO4.	Magnesia.	Lime.	Bicarbonates.		str. = strong. m. = moderate. w. = weak. — = none.
Sample.	*Parts in 100,000.*				*Qualitative.*				*Remarks.*
Salton Sea No. 1....	330.0	243.5	31.6	40.6	m.	str.	?	—>	Samples 1-9 incl. are all of same general character. About ⅔ t. s. is Na Cl W. some lime and mag. as bicarb., but mostly as sulphate; and an excess of SO4 combined as Na SO4.
" 2....	331.2	242.5	32.1	41.9	"	"	w.		
" 3....	336.0	249.0	35.0	42.2	w.	"	"		
" 4....	321.8	238.0	33.7	41.0	str.	"	"		
" 5....	330.4	242.0	28.3	41.9	"	"	"		
" 6....	327 0	240.0	29.9	42.3	"	"	"		
" 7....	330.6	246.0	28.8	41.3	"	"	"		
" 8....	338.4	249.0	28.3	43.7	m.	"	m.		
" 9....	258.8	185 0	27.2	35.8	w.	"	?		
" "A" surf.	338.2	250.0	30.5	41.8	str.	"	w.		
" "A" 10'..	338.6	250.0	27.7	42.3	"	"	"		All this set of same general character as 1–8, showing very little influence of depth on samples.
" "A" 30'..	340.0	250.0	27.2	42.2	"	"	"	—>	
" "B" surf..	341.8	250.5	28.3	42.4	"	"	"		
" "B" 10'..	338 6	250.0	33.2	41.7	"	"	"		
" "B" 60'..	352.0	259.0	36.0	44.1	"	"	"		

The main and maximum level beach line of the ancient lake is well marked more than three-fourths of the way around the basin; but of much greater interest are the numerous minor beaches, which may be traced with ease on the steep western slope of the basin near Travertine Point. These are denoted by denser belts of vegetation (see Figure 5), from which it is evident that the water has stood at various levels for lengthy periods at various times. It is not to be taken for granted that these beaches represent one series of successive levels in the recession of the water from the maximum size. It is more probable that they attest the height of various fillings, like the one now under observation.

According to present observations, the minor beaches are best traced by vegetation on steep, gravelly slopes. When the water stands at any level for even a brief period, the action of the waves results in a caving bank being formed. Immediately at the foot of this bank the water exercises a sorting action, so that when the lake recedes from this level it leaves behind a vertical crumbling bank of gravel, a zone just below it in which the coarser and finer material have been separated, and in which drift and, perhaps, seeds have been lodged. It is evident that with this beginning a difference in the occurrence and distribution of plants reoccupying the submerged area might be noticeable after the lapse of many centuries.

The present level of the Salton gives it a superficial area of between 600 and 700 square miles. The area flooded was occupied with halophytic plants around the saline springs and salty areas and of spinose forms in the drier areas. The recession of the lake will doubtless be followed by a reoccupation of the basin by these two forms of vegetation. Many of the deserts of the world comprise extensive areas formerly in submergence.

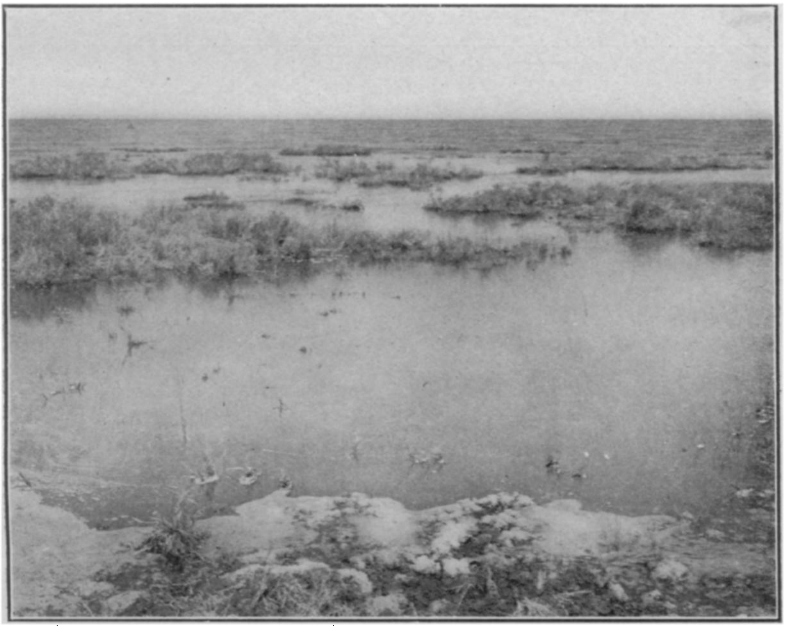


FIG. 3.—MARGIN OF SALTON SEA NEAR TRAVERTINE POINT, MAY 22, 1907: LEVEL RISING RAPIDLY.

The recession of the Salton Lake, therefore, will afford the botanist an unparalleled opportunity for the observation of the movements and behaviour of plants in the occupation of a denuded area, which should afford distributional data of prime importance, and may also yield facts of great importance in the study of the physiological adaptations of xerophytic and halophytic plants.

Such an investigation has been undertaken by the Desert Laboratory of the Carnegie Institution, and observational areas have been surveyed on the present shore, which will be extended as the lake recedes down to the bottom of the bowl. One such area lies on the gentle slopes of alkaline loam near Old Beach, another in the mesquite-covered flats near Mecca, another includes a sand wash and adjacent banks, and another is located on the gravel slopes on which the old beaches are so plainly recorded. One of the most interesting comprises Obsidian Island, off the shore from Old Beach, in which it is proposed to follow the course of events in the enlarging area of the island, and to note the result of the laying bare of the neck of land connecting with the shore of the lake. In addition to the movements of the vegetation now established in the basin, it seems a fair probability that plants and seeds brought down by the Colorado current may find lodgment on the moist shores and become established under conditions slightly different from those of the habitat from which they came.

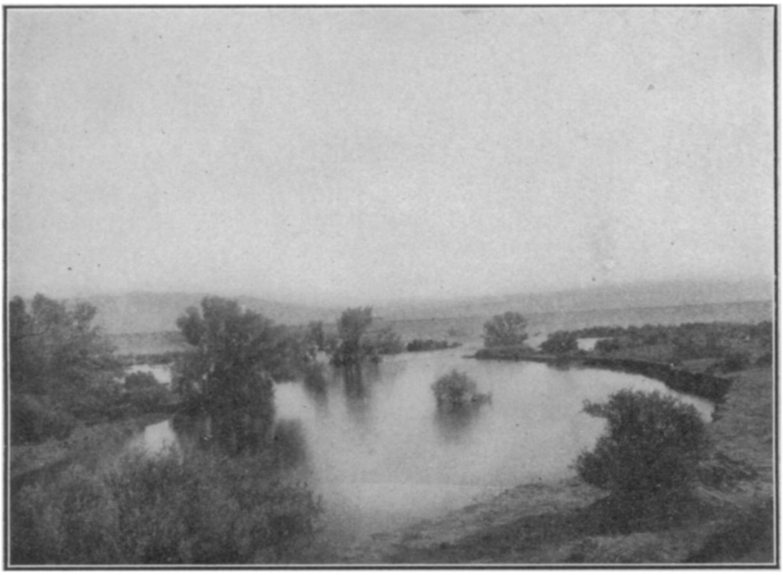


FIG. 4.—DESERT WASH, INVADED BY AN ARM OF THE SALTON SEA. FEBRUARY, 1907.

The actual margin of the lake presented a very singular aspect at the time of the recent expedition, since no real beach existed. The advancing waters encroached upon the desert vegetation in such manner that, within a few feet of the shore, growth was continuing as usual. Some shrubs stood with their feet in the water, while others ran farther out in a series which showed less and less of the tops, until perhaps a half mile from the shore one might steer through the submerged tops of mesquite and *Parosela* soaking in the salty water. The dry washes that come down the sides of the bowl cut shallow *barrancas* with vertical walls and broad floors, in which shrubs and herbs become established in the long intervals between the occurrences of running water in these drainage-ways.

The *salses,* or mud volcanoes, which lie near these small buttes were all covered at the time of our visit and nothing of their activity could be detected. Dr. Veatch visited the place in July, 1857, and by his account the active vents occupied a parallelogram five hundred by three hundred and fifty yards, the mud, steam and water escaping with such force that they were thrown many feet into the air with noises that could be heard for several miles (Veatch, J. A. Notes on a visit to the "Mud Volcanoes in the Colorado Desert in the month of July, 1857, Am. Jour. Science and Arts, 2d Ser., 26:288, 1858. *See* also Le Conte: An Account of Some Volcanic Springs in the Desert of Colorado in Southern California. Amer. Jour. Science and Arts, 2d Ser., 19:1,1855).

Long tongues of water extended up these barrancas, sometimes to a distance of a quarter of a mile or more from the general shoreline, and in these the roll of the lake was converted into oscillations of rising, advancing currents, which would set upstream for several minutes and then reverse, leaving a long stretch of moist soil or mud.

Several small volcanic hills of ancient origin occur in the basin southwest from Old Beach, and these have been cut off by a sheet of water with a depth of about 30 feet. The soil is highly alkaline, the slopes show minor beaches, and the restricted vegetation was supporting a few rabbits at the time of our visit, and these in turn were being preyed upon by a coyote and raccoons.

Observations upon the relative humidity were during the course of a camp on shore among the sand dunes of Carrizo creek. Within a narrow zone, 4 or 500 yards in width, fringing the shore a relative humidity between 80 and 90 per cent. was found on the afternoon of a day without wind. Outside of this the proportion decreased rapidly, so that at a thousand yards but 49 per cent. was observed; beyond which the unchanged aridity of the desert was soon encountered. The maintenance of the lake at any given level for two or three years would doubtless result in a zone of shrubs and other vegetation near the shore, resulting from the abundant supply of moisture; but little influence may be noted beyond this. Conditions of relative humidity on the desert at the eastern margin of the moist delta were described in the last article upon this region (BULL. Amer. Geog. Soc., January, 1906, p. 4). To predicate any further change in the Colorado Desert, either in climate or vegetation, as the result of the formation of the lake, is to make assertions not in consonance with existing facts, nor in harmony with the theoretical conditions.

A second depressed basin formerly connected with the Gulf lies to the south of the Salton across the international boundary, between the Cucopa Mountains and the main range of the peninsula of California. But little systematic information upon it may be found, although an intermittent salt lake in it has long been known under the name of Laguna Maquata.

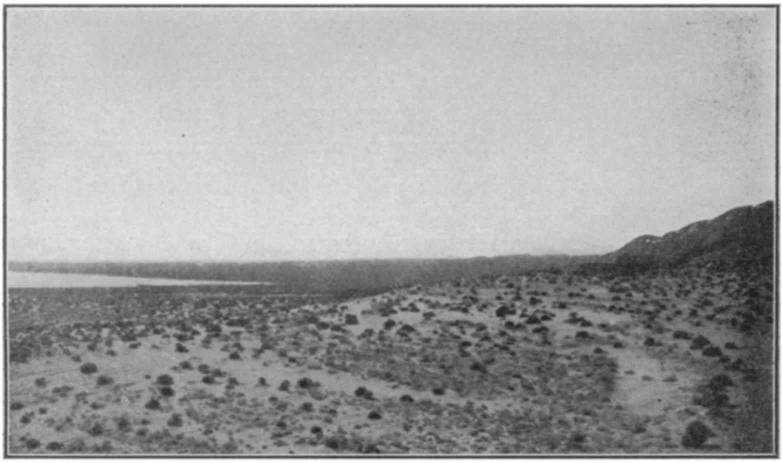


FIG. 5.—TERRACE OF ANCIENT BEACH ON THE RIGHT AND SALTON SEA AT MAXIMUM LEVEL. FEBRUARY, 1907. MINOR BEACH LINES ARE INDICATED ON THE GRAVELLY SLOPES BY BANDS OF VEGETATION.

Brief mention was made of this region in a previous paper (The Delta of the Rio Colorado, BULL. Amer. Geog. Soc., January, 1906), the inflowing waters of the delta having been noted from the summit of the Cucopa Mountains in April, 1905. Our recent expedition outfitted at Calexico, and traversed a route to the westward across the northern end of the Cucopa Mountains, through a pass south of Signal Mountain, and southward along the eastern side of the basin, doubling around the southern end of the mountains, and coming northward through the delta over ground previously examined by us.

The data obtained in this manner are of unusual interest, since it is indubitably proved that this basin is also an ancient arm of the Gulf, from which it has been cut off more recently, and that it now, like the Salton, is an integral part of the delta. Furthermore, the lake within it is re-filled at intervals, much more frequently than the Salton, while at times the bottom of the basin is left bare. Briefly expressed, it is repeating the history of the last named, and is now in the condition which might reasonably be ascribed to the Salton a few thousand years ago.

This basin, which for reasons given below we have designated as the Pattie Basin, lies nearer the Gulf, and has a more direct connection with the drainage of the delta, and, as will be seen, has not yet developed the connecting channels, which have formed such an important feature in the flooding of the Salton.

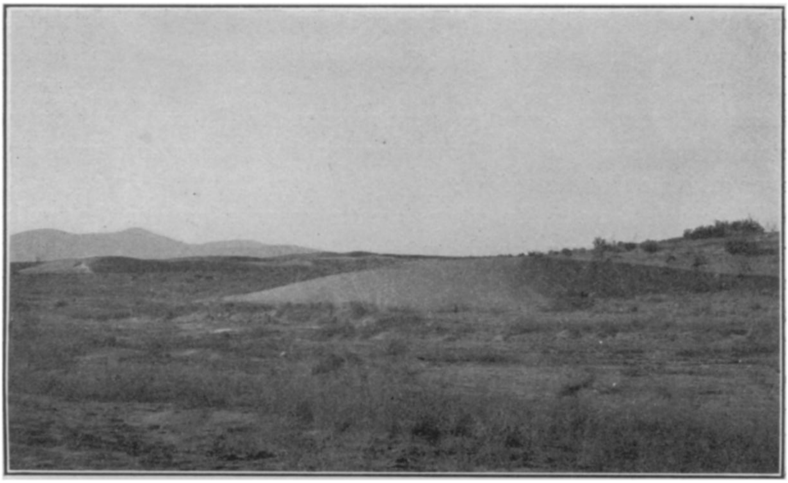


FIG. 6.—CRESCENTIC DUNES IN THE SANDS OF CARRIZO CREEK.

The flood waters of the delta bathe the entire eastern base of the southern half of the Cucopa Mountains, locally known as the Mayor, and the collecting channel, the Hardy River, comes against the granite rock about midway of the region of the contact (see map). Ordinarily this stream, which issues from Volcano Lake, carries the seepage from the alluvial soil and the feeble flow from the lake, but during high water all of the flow of the western part of the delta is collected by it, as it thrusts an elbow against the mountain. Turning to the southeastward toward the Colorado, a great volume of water leaves it in various low places along the ridgy bank and slips gently to the southward, collecting in an open *laguna* two or three miles from the main channel. No great depth is attained except in shallow depressions that have been cut in the loam by the current, and the level of the flood may be seen on the stems of the mesquite, which forms dense jungles over most of the delta and upon the rocky foot of the mountain. The inundation begins ordinarily in late May or early in June, and lasts two months or more—a sufficient time to cause the mesquite to form prop roots, which emerge from the hard stems two or three feet from the ground and attain a thickness of half an inch in some instances; an action by no means common with this tree.

The jungle formation of mesquite and other shrubs does not extend to the southern end of the mountains, and the flood waters emerge from it and spread out over a great saline plain which extends far to the southward along the Colorado and the head of the Gulf, and which, in fact, is a portion of the delta. A high-water channel leaves the Hardy before it reaches the Colorado and makes around southward and eastward through this plain, returning to the river at some distance below.

The western extension of this great plain runs between the southern end of the Cucopas and the coastal ranges, a width of 12 to 15 miles, and curves northward around the western side of the Cucopa Mountains.

The course of the water indicates that from near the southern end of the Cucopa Mountains the slope is northward. Alkaline moist spots are seen in places when the plain is dry, whitish saline deposits in others, and extensive stretches of caked surface are found with a shallow rhomboidal cleavage. During floods the water following the gradient in a shallow sheet ten to twelve miles wide, with a depth of only a few inches or two or three feet at most, becomes highly heated in the rays of the vertical sun, as it moves slowly northward. West of the Mayor it encounters a zone of short sedge, two or three miles in width, apparently extending from mountain to mountain. Next a series of channels is encountered, which run athwart the plain and head in toward the base of the Mayor. These channels are cut to various depths as great as 15 or 20 feet, are extremely tortuous, and, although the drainage is of the indefinite character that might be expected under the conditions, they finally form one large channel leading northwesterly toward the base of the peninsular range. The slowly moving flood waters fill the main system, and overflow the plain on both sides, eroding parallel troughs, or channels of indefinite length, many of which begin and end blindly. The whole series are known to the Indians as Las Barrancas.

The accumulated water forms a lake about forty miles in length and twenty in width, which extends from the Cucopa Mountains on the east to the base of the main range on the west at its highest level, and has long been known as Laguna Maquata by the Indians and Laguna Salada by the Mexicans. It is to be seen that here is a condition of affairs very similar to that in the Salton Basin. According to the testimony of Mr. H. A. Jenkins, a cattle man of some experience in the delta, this system of barrancas has nearly doubled its length within the last ten years, within which time it has developed the upper course and the branches, shown on the map accompanying this article. It is fair to presume that if a canal were cut from the Hardy channel to the head of one of these branches, the action of the flood waters during the next overflow would bring about results fairly similar to those which have come about in the Salton during the last three years, following the opening of the river bank and the excavation of canals connecting its channel with that of the Alamo. The slope is hardly so steep as in the Salton, however, and the action would probably not be so rapid.

The winter floods of 1905-1906, which sent such enormous volumes into the Salton, also filled the Laguna Maquata to a high level, and this had receded at such a rate that at the time of our visit it had less than a third of its recent maximum area. Another year or two without accession from the delta and its floor would again be dry, as it has been seen to be on more than one occasion.

Observational records concerning the movements of the Laguna are very sparse. Mr. C. R. Orcutt reported (The Colorado Desert, Tenth Rep. State Mineralogist of Calif., 1890) that it was of great size in 1884, at which time great volumes of water passed through New River to the Salton. The Laguna had dwindled to a chain of salt pools in February, 1890, although it might have filled and receded between these two dates, and was also very low and salty in 1892. It is not known whether or not it filled in 1891, at which time Salton received much water from the river. According to information furnished by Mr. H. H. Silsbee, who has conducted extensive surveys in the delta lands, the Laguna filled again in 1893. An outflow from the Hardy passing around the southern end of the mountains into the Laguna was reported in June, 1907; and this probably occurs during almost every annual flood. A consideration of these and of the general conditions leads to the belief that the Laguna and Salton receive water from the river quite independently of any common cause, except that of a flood in the Colorado, which may enter one or both, according to various factors affecting the flow.

When filled to its maximum level, the waters stand several feet deep against the steep, impassable granite walls of the mountains on both eastern and western shores, and at such times the basin is, of course, impassable. The drying up of the lake, however, leaves its floor as great stretches of smooth, hard saline surfaces, furnishing unexcelled waggonways, and over this extensive smuggling operations have been conducted at times. A line of communication known as the Campo road passes through the basin, but has been a possible route at low water for the infrequent prospector, rather than a used thoroughfare.

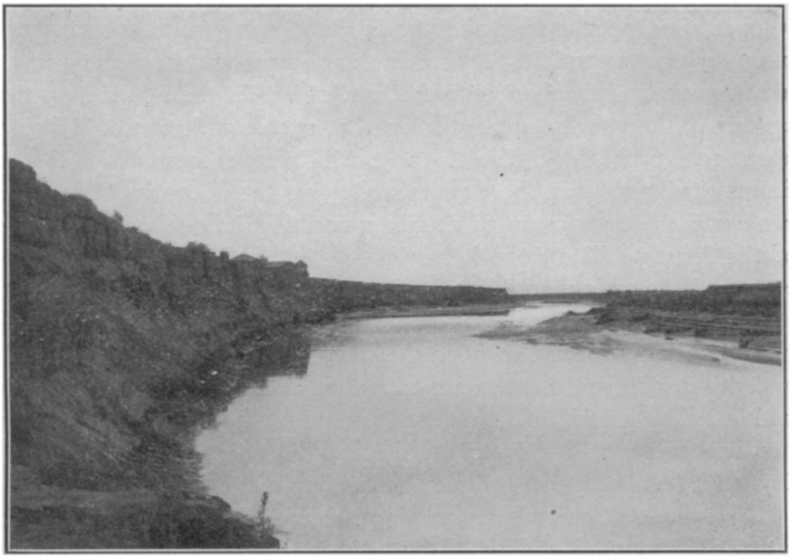


FIG. 7.—CHANNEL OF NEW RIVER AT THE INTERNATIONAL BOUNDARY. MEXICALA FORMERLY OCCUPIED A SITE OVER THE MIDDLE OF THE CHANNEL, AND REMAINING BUILDINGS ARE TO BE SEEN ON BANK AT THE LEFT.

At the time of the recent visit to the lake the level was many feet below that reached during the inflow of a year ago, and on the gentler slopes the shore was fringed with a muddy zone as much as half a mile wide in places, which rendered it impossible to reach the water. Near the upper edge of this band of salty mud was a windrow of remains of fish, which appeared to be carp, according to the results of an examination by Mr. Herbert Brown of the party. This low ridge of dead fish was seen to extend for about fifteen miles, and may have been double that length. A similar observation was made by Orcutt in 1890, who found that the remains at that time were of mullet. From other reports it seems fairly probable that nearly every flood brings in with it shoals of fish which find their way into the Laguna. The shallow sheet coming in over the plain to the southward must furnish abundant food; but as the water rises in temperature and increases in concentration, it seems quite probable that a point is reached at which the waters become poisonous to all of the finny inhabitants. Furthermore, this condition ensues at once and with sweeping effect, for the dead fish go ashore during so brief a period that no marked change of level has taken place; and as evaporation may be as great as a half-inch a day, and is scarcely ever less than a quarter, the disaster must take place within a week or two. In February, 1907, the Laguna contained 10548.8 parts of salts to every hundred thousand, and crystals of Calcium sulphate were being formed along the margin (see table).

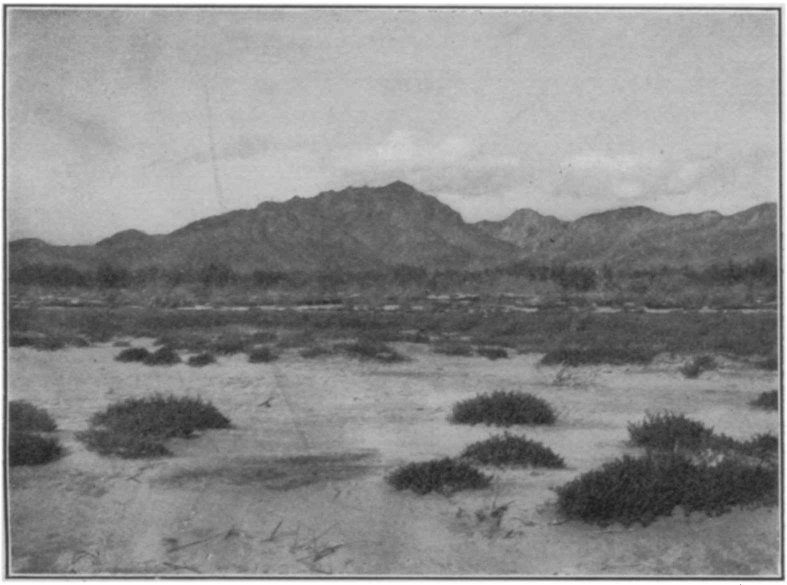


FIG. 8.—FOREBEACH OF LAGUNA MAQUATA, WITH BELT OF MESQUITE IN THE BACKGROUND AT HIGHEST BEACH-LINE. CUCOPA MOUNTAINS IN THE BACKGROUND.

A length of seven or eight miles of the lower part of the channel of the main barranca contained water which was extremely highly charged at the upper southern end and contained 742.2 parts in 100,000 two or three miles below; while Mr. H. A. Jenkins reported that it was generally found to be drinkable at the extreme lower end, which would imply the presence of less than 250 parts in

100,000. The only plausible explanation that could be offered was that the highly-charged saline soils of the plain were covered with silt in the lower portions of the barranca, and that the water remaining there was thus kept sweet. Mullet and carp were found in the channel visited.

The best evidence as to the movements of the lake-level was that afforded by the vegetation surrounding the main body of water. The extreme high-water mark during the present condition of the basin is denoted by a zone of mesquite a quarter to a half mile wide, which runs around the lake, being interrupted only where the shore comes against the granite or volcanic slopes. Inside the mesquite was a narrower zone inhabited by salt-bush and mallows, marking possible levels of 1884, or 1893, while immediately inside of this was another zone a few yards in width, bearing only clumps of the sea-purslane, which thrives only in moist saline soil, and which with but little doubt stands on the shore of the lake at its greatest level in 1905-1906. Among these clumps were to be seen the remains of other desert plants which had become established at this level since the previous inundation. These formations were remarked with extreme interest, since similar zonation, with consequent succession, may be expected in the long periods of rise and recession of the Salton.

	Total Solids at 110° C.	Chlorine, stated as Na Co.	Hardness by Heburs test, stated as Ca SO4.	Sulphate by Ba SO4 stated as SO4.	Ma nesia.	Lime.	Bicarbonates.		str. = strong. m. = moderate. w. = weak. — = none.
Sample.	*Parts in 100,000.*				*Qualitative.*				*Remarks.*
Pozo Coyote....	245.0	136.5	$Na_2 CO_3$ 36.5 $Ca SO_4$	30.7	?	w.	w.	—>	Characteristic black alkaline. (Seepage from granitic country.)
Barranca........	742.2	550.0	111.4	110.7	str.	str.	"	—>	Also $H_2 S$; no Li or K *
Hot Springs....	2489.0	2196 0	522.2	32.2	w.	"	—	—>	no $H_2 S$ or K; Li slight †
Maquata	10548.8	8570.0	87.0	975.2	str.	"	str.	—>	Strong $H_2 S$; slt. Li & K §

* About the same relative composition as 1-9 but concentrated ∓ 2½ times.

† Deficient in SO_4 and Mg. but with great hardness due to $Ca Cl_2$, ∓ .5% w. ∓ 2.% Na Cl.

§ Showing a greater proportion of salt and a lesser proportion of sulphates as if $Ca SO_4$ might have been pointed out, leaving Na Cl and $Na_2 SO_4$; and the salt deposit from edge of lake is found to be mainly $Ca SO_4$.

—> Lithium in lake apparently derived from hot spring.

Midway of the eastern margin of the lake at its level, the expedition encountered a spring, the waters of which gave temperatures

112° F. to 128° F. when tested with two reliable thermometers. The steaming pools were sheeted with an algal formation consisting of *Phormidium tenue,* and a second species of the same genus to be named *Phormidium tenuissimum,* the latter being identical with a species in the hot springs of Yellowstone Park, according to Professor Setchell of the University of California, to whom they were submitted for examination. Darting around among these blue-green masses were numbers of a small fish which reminded the novice of a trout. The waters were so warm that the hands could not be held under the surface very long; but finally a few of these were captured, and, to our astonishment, remained alive when kept in camp in a vessel of the spring water, which soon fell to air-temperatures of 80° and down to 50° F. Furthermore, when placed in formalin, they were highly resistant to its action. Some of these specimens submitted to Dr. D. S. Jordan were found to belong to an undescribed species of rainwater fish, and were accordingly named *Lucania Brownii* by him. The capacity for endurance of these animals to external factors may be realized when reference is made to the composition of the water as shown in table, page 722. Still more interesting is the fact, to which my attention has been called by Dr. B. W. Evermann of the U. S. Fish Commission, that in this spring is the only known occurrence of a rainwater fish in the Pacific drainage.

As soon as the status of this valley was realized by the members of our expedition, it was determined to designate it as the Pattie Basin, in recognition of the first recorded visit to the place by the Patties, father and son, with their party in 1828. This party of trappers descended from Yuma in an effort to reach the Spanish settlements to the southwest, and, after some struggles with the floods and tides at the mouth of the river, cached their extensive store of furs and started westward from the main channel, traversing the mesquite jungles of the delta lands and crossed the Cucopa Mountains, probably at some pass in the Sulphur Mine Range, the lower central series of ridges, and then made across the basin in a two-days' march to Palomar Canoñ, or Agua Caliente, coming down from the peninsular ranges. The mission of Santa Catarina was reached first, and from thence they were taken as prisoners to San Diego. Whatever doubt may be held as to the accuracy of the account of the wanderings of this party from Yuma northward, it is to be said that the description of the journey from the Colorado River to the mountains of Baja California is well in accord with the facts as we have found them, and the hardships of the journey across the Pattie Basin are portrayed in a manner impossible to any one who has not actually experienced its rigours (The Personal Narrative of J. O. Pattie, 208-228, 1905). It is by no means improbable that some portion of the basin or its laguna may have been glimpsed by Father Kino two centuries ago; but no direct evidence is at hand, and many easier and more profitable routes are offered in the extensive missionary work carried on by him with such vigour. The map by Font in 1777 shows an arm which might well mean the extension of the delta waters into this basin (see Fig. 11). Father Garcés, on his fifth visit to this region in 1775 and 1776, undoubtedly made as far south as the mud flats south and west of Montague Island, and in so doing saw the great open plain leading into the basin. He says:

> Thus I perceive that at time of the great risings of the river the water can very well overflow this valley or strand that there is between the two sierras of Santa Barbara (Cucopa Mts.) and of San Gerónimo (the main range south and west of the Cucopa Mts.) as far as the place where the first expedition [of 1774] found stranded that heap of fish of which is made mention in the diary (The Diary and Itinerary of Francisco Garcés, by Elliot Coues, 1:194, 1900).

The diary has not been accessible, but this last paragraph indicates that a passage had been made through the Pattie Basin when the water in the Laguna was at a low stage and that remains of fish similar to those mentioned above were found.

It is to be noted that the unfamiliarity of the editor of Garcés' Diary with the features of the lower delta has led him to persistently deny the correctness of the positions given by this Spanish pioneer. Garcés' route may be traced with ease on the map accompanying this article to a point as far south as Antelope Slough, where, finding only bare flats and no drinkable water, he turned north.

The Cucopa Indians who have inhabited the lower part of the delta about the mouth of the Hardy for some time, singularly enough, hold the closest communication and intermarry with the tribes inhabiting the mountains to the westward of the basin. Two main trails are used. One crosses the Cucopa Mountains in the vicinity of the Borrego Peak, going up from the delta through a long cañon heading toward the southwest. Agua de las Palmas is the first watering-place, and this spring is reputed to be named from the group of palms which surround it, probably the only plants of this kind in the whole range, although Barrows mistakenly ascribes to them a wide distribution in this region (National Geog. Magazine, 11, 347, 1900). The main ridge is crossed through a low pass, and then the way leads through granite, volcanic and clay ridges to where, among the bad lands, a seepage in a sand wash, known as Agua de las Mujeres, furnishes a small but unfailing supply. From here a blind trail leads, straight as may be, due west across the valley to the mouth of the Palomar Cañon, up which, at a distance of about three miles, running water and the grateful shade of groves of palms may be encountered. This has long been a favourite camp and meeting-place for the Indians, and one of the attractions of the place is the quantity of agave, growing on the slopes, from which mescal is baked and brewed.

The trail from Agua de las Mujeres to Palomar Cañon passes to the south of Laguna Maquata, and it makes a distance of about 30 miles across a desert plain, baking in the vertical rays of a tropical sun. The route is found entirely by directions or ranges on somewhat indefinite topographical features, and it requires experience and a stout heart to dare the journey in midsummer. The great sheet of the flood which fills the Laguna at times moves across a

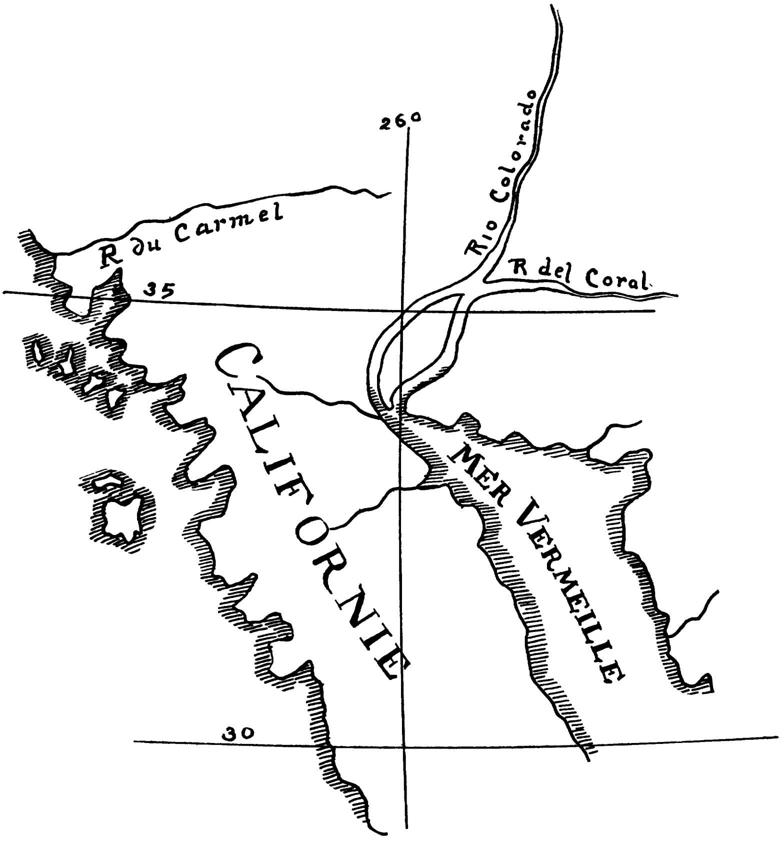


FIG. 9.—REGION AROUND THE MOUTH OF THE COLORADO RIVER, SHOWING TWO CHANNELS. BY GUILLAUME DE L'ISLE. CARTE D'AMÉRIQUE, PARIS, 1722.

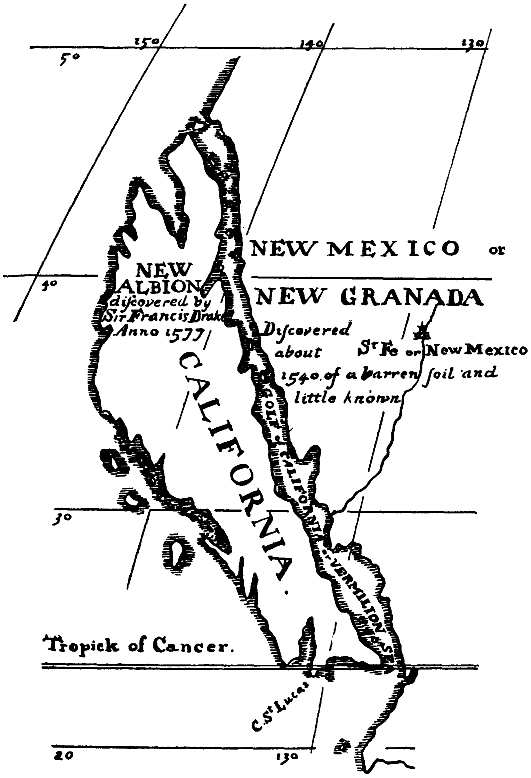
section of this trail several miles in length, covering it to a depth of a few inches or a few feet, and a passage might be made by a horseman at such times. In one instance a Mexican prospector out of provisions made it afoot, feeling his way cautiously over the slippery muddy bottom so slowly that two days and the intervening nights were consumed in reaching Agua de las Mujeres. The hot, salty water underfoot, the blazing sun, clouds of mosquitoes and insects, together with an insufficient supply of water in his small canteen, formed a combination that tested his powers of endurance to the uttermost.

The second intertribal trail starts from near the point where the flood waters leave the channel of the Hardy and climbs over the southeastern spur of the Cucopa Mountains, descending to Pozo Coyote due south of the main range. Here water containing black alkali is found, and, when used constantly, the proportion present is less than one-fourth of one per cent., but when allowed to stand and evaporate the percentage rises to an injurious figure. From Pozo Coyote the trail runs across the bare, flat plain in its upper slope, where the water starts northward to Laguna Maquata in times of flood and makes either to a *tinaja* at the northern end of a series of small mountains, known as the Tinaja Range, or up a wide valley farther to the southward, Arroyo Grande. This latter route is one much traversed by Indians and Mexicans, as it affords the easiest grades from the backbone of the peninsula to the Colorado River, and is composed of short tangents from water to water. Our expedition, which traversed the eastern side of the Pattie Basin, found permanent water supply only at Agua de las Mujeres. North of this, about twelve miles, a deep *cajon* which cut down through a foothill of red conglomerate had a number of kettle holes, or *tinajas,* which contained water at that time, but these could not be relied upon in times of great aridity. The contents of Las Barrancas were used sparingly by our horses, but were too concentrated to allay thirst. Pozo del Coyote offers an unfailing supply, but if not visited by any traveller for two weeks it becomes poisonous. Thus it may be seen that but one reliable source of water is to be found on all of the western slopes of the Cucopa Mountains.

The information obtained by our various examinations of the region shows that the area to be included in the delta is much more extensive than ordinarily supposed. In addition to the alluvial lands near and below Yuma, extending to the mouth of the river, the triangular tract subject to overflow east of the mouth, including the channel of the Santa Clara Slough and extending as far south in

Sonora as 31° 45′ N., is an integral part of the land made by the river. The Salton Basin, extending 180 miles northwest from the river, the Pattie Basin, curving around from below the mouth of the Hardy up to near the international boundary, and also the alluvial plain on the western shore of the Gulf as far south as 31° 15′ N., are to be included.

This plain has not previously been considered as a portion of the delta; but it is made up of river deposits, is traversed by flood channels which leave the Hardy near its junction with the Colorado, and much of the surface bears drift brought down from the upper course of the river.


150
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NEW ALBION diſcovered by Sir Francis Drake Anno 1577
CALIFORNIA
NEW MEXICO or
NEW GRANADA
Dyſcovered about 1540. of a barren ſoil and little known
St Fe or New Mexico
GOLF of CALIFORNIA or VERMILION SEA
Tropick of Cancer.
C. St Lucas

FIG. 10.—LOWER CALIFORNIA AS AN ISLAND. BY M. BURG, IN "A NEW MAP OF NORTH AMERICA," OXFORD (PROBABLY ABOUT 1700).

The difficulties of travel in all of the delta may well be taken to account for the diversity shown by the earlier maps of the head of the Gulf. Some of the curious branches shown on the old maps might be taken to indicate that the Laguna Maquata or the Salton Sea had been noted by the explorer. The wide expanse leading around between two great mountain ranges into the Pattie Basin might well justify the observer from the Gulf in the belief in the Strait of Anian, and this belief would be strengthened if his route led him to encounter the waters of the Salton a hundred miles to the northwest.

Something of the outflow channels of the Colorado in the delta is shown on a Spanish map of a century ago, as illustrated in the portion reproduced in Figure 11. The channel curving to the westward would represent the system of the Pescadero and Hardy of the present time, although it is to be noted that all of such channels might change form and position in the most radical manner in a few decades.

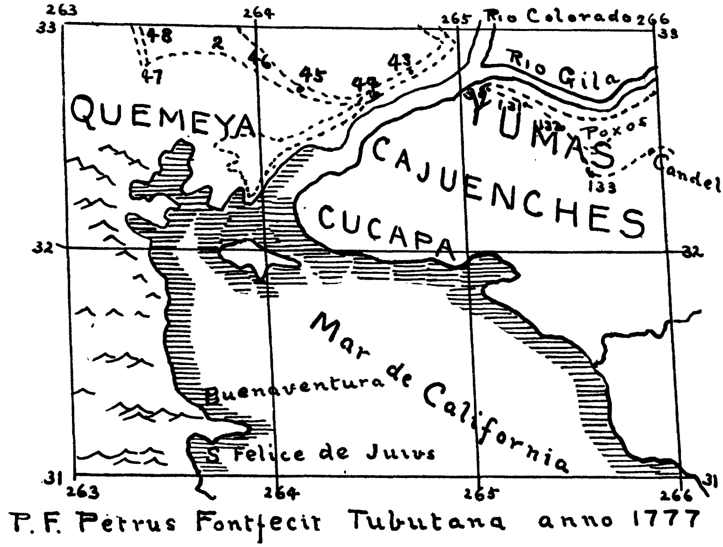

FIG. 11.—MAP OF THE HEAD OF THE GULF OF CALIFORNIA BY FONT, 1777, IN WHICH AN ARM IS SHOWN WHICH MIGHT HAVE OCCUPIED THE PATTIE BASIN.

The study of the origin and movements of the flora of this region, which has been undertaken by the staff of the Desert Laboratory, entails a consideration of the more recent geological history, together with the present features of importance to vegetation.

The Gulf originally divided into three main branches at its upper end, and into their narrowing straits the tides have always piled up to heights which at present reach over 30 feet. The river emptied into one of the arms, and the silt piled up and moved by tides and currents, together with possible changes of level, has filled up one arm to form the low lands near the present course of the channel, and made a barrier across the inlets leading into the two other arms which, now arid and intermittently flooded from the river, form the Pattie and Salton Basins.

In addition to the slow movement of the jungle vegetation seaward with the southern extension of the central portion of the alluvial lands, other major movements of great sweep have taken place. The depressed basins, once a part of the Gulf, have been occupied by various types of xerophytic and halophytic vegetation, by encroachment from the contiguous desert, and by the aid of the inflowing river floods from great distances, and many opportunities have been offered for the origin and adaptation of new species either by direct response or by the chance saltation, which might bring a new form into existence in an environment exactly suitable for its maintenance.

The Cucopa Mountains are in effect a desert range, connected with other high land by a narrow ridge crossing the international boundary, and their arid slopes on the other hand offer conditions of almost absolute isolation, being cut off from the mainland of Sonora and Baja California by low basins and moist alluvial plains, and offering conditions favouring endemism. We thus have a desert island in the midst of a great area in which the distributional movements of vegetation have been of unusually wide amplitude and the possible interchanges of living organisms have been of an exceptional character.

LETCHWORTH PARK PRESENTED TO NEW YORK STATE.

Governor Hughes, in his inaugural message to the Legislature of New York on Jan. 2, 1907, made the following communication:

> It is my privilege to lay before you the public-spirited proposal of the Hon. William Pryor Letchworth to convey to the people of the State of New York 1,000 acres, approximately, situated in the town of Genesee Falls, Wyoming County, and the town of Portage, Livingston County, upon which Mr. Letchworth now resides.
>
> He desires to dedicate the land to the purposes of a public park or reservation, subject to his life use and tenancy, and his right to make changes and improvements thereon. If it is your pleasure to provide for the acceptance of the gift, the State will thus obtain title to a tract of rare beauty, the preservation of which, for the purposes of a public park, cannot fail to contribute to the advantage and enjoyment of the people.

Late in the same month an Act accepting the gift was passed, and became the first law of Gov. Hughes' administration. It is provided